REVIEW OF LITERATURE
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Domestic animals have been considered an integral part of farming since the dawn of human civilization. These have provided milk, meat, egg, leather, companionship and labour and greatly contributed to the development of rural stability and an enduring agriculture (Cheeke, 1987).

India has a large livestock population with about 192 million cattle, 69.8 million buffaloe, 48.4 million sheep and 95.4 million goat, besides an unlimited number of non-ruminants (Acharya, 1993). Traditionally, mixed farming is practiced in several parts of rural India where maintenance of livestock has been an integral part of agriculture (Patil et al., 1993). The crop residues are generally used as livestock feed and soil enrichment has been accomplished by addition of farm yard manure.

Increasing human population demanded higher quantum of food production all over the world (Yotopoulos, 1987). Various estimates indicate an increase of 70-90 million people annually, with 87% of this growth occurring in the countries not able to feed themselves (Cheeke, 1987). Since the productivity value of farm animals is very low in India, it was necessary for marginal income-group farmers to maintain a large number to meet the regular requirement of meat and milk. Major portion of crop land has been used for
production of cereals and consequently fodder cultivation was grossly neglected in India. Industrial use of roughage for paper- and board-making and domestic burning of agricultural by-products and fibrous waste for cooking is also on the raise. These all together resulted with shortage of fodder without which livestock rearing would be uneconomical.

A. LIVESTOCK FARMING AND FEEDS

a. Livestock farming:

Use of livestock as an efficient instrument to convert fibrous crop residue into nutritious food, viz. milk, meat and egg, has been realized well before (Mudgal et al., 1995). However, the crop residues are poor in providing adequate energy and nitrogen due to the complex structural arrangement of plant cells. Physical degradation methods such as soaking in water, powdering and crushing have been attempted (Mathur and Sharma, 1985). Chemical treatment of fibrous feed has also been tried long before. Alkali-treated straw was fed to cattle in Germany during World War I (Ranjhan, 1983).

In livestock production, with introduction of high yielding animals and nonavailability of enough forages and roughage sources, more emphasis was given on concentrate feeding than roughage in the recent past. An increase in concentrate feeding by 2.6% as against 1.2% for fodder has been recorded
The past decade also saw an increase of 20% in nonruminant population as against 8% in ruminants and this was attributed mainly to nonavailability of adequate roughage (Agostini, 1987).

Presently, an estimated 700 million people do not get sufficient food around the world. Hunger and malnutrition are said to be on continuous raise in developing countries. It is predicted that there will be a deficit of 208 million ton food by 2000 AD (Paroda, 1996). Of the food grains, cereals are the major source of calorie in-take for people of low income household. It is now well realized that domestic animals are the major competitors of men for food grains. Out of the total world grain production, 47% is consumed as food by humans, 39% as feed by animals and the remaining 14% used for industrial purposes (Yotopoulos, 1987).

Broiler production has increased from 10 million to 200 million in the last two decades (Chadha, 1991). Similarly, population of other meat-animals has also been increased considerably to meet the increasing demand of protein-rich food. Concomitant with this, a 44% deficit in feed and 34% shortage in fodder is anticipated by turn of this century in India (Mudgal et al., 1995). Therefore, there is an urgent demand to identify ways and means by which the competition between man and animal for grains can be reduced. Assuming a
10% growth in layers and 20% increase in broilers, 11 million tons of poultry feed will be required by 2000 AD over the present requirement of 4.5 million tons. In order to meet the demand, the following alternate measures were recommended by Rao and Rakshit (1991) for careful consideration: (i) finding out newer sources of feed ingredients, (ii) use of additives to improve efficiency of utilization of feed and fodder, (iii) reducing the feed wastage, (iv) increased use of agro-industrial by-products and waste as feed and (v) increased use of nonconventional feed ingredients.

b. Search for better feed substitutes:

Rayton and Hall (1979) developed improved feeding technology in poultry farming so as to reduce feed wastage and successfully increased the efficiency of egg production. Various feed resources such as babul seeds and mango kernel were tried as substitute for costly feed ingredients in farm animals and poultry development (Rao et al., 1986; Shukla et al., 1991,).

Efforts were made to identify economic feeding practices in livestock development. Various feed additives were added to improve digestibility of concentrate feeds. On adding yeast culture extract as crude protein source in cattle/poultry diet, improved performance was observed by Wiedmeier et al. (1987) and Verma and Shyamsundar (1988). Addition of
biodegradable enzymes to feed ration was attempted by Devegowda (1991) and Chen et al. (1995) to achieve higher digestibility.

Use of agro-industrial by-products and waste as animal and poultry feed substitute was reported by several workers (Punj 1991; Sawal et al., 1995). Ranjhan (1983) incorporated molasses as an alternate to grains in cattle ration. Waste materials such as rubber seed cake (Anantha subramaniam, 1980), animal waste (Hazarika, 1994), spent tea (Sud and Dogra, 1993) and sugarcane bagasse (Chaudhary et al., 1994) were fed to livestock as substitute to costly feed ingredients.

Although little success was achieved, incorporation of unconventional items such as poultry waste in cattle and sheep feed (Paul et al., 1994; Puntambekar et al., 1991) and cow dung in poultry feed (Saikia et al., 1988) was some of the efforts tried to overcome feed shortage and to improve the feed quality. Chademana and Offer (1990) added yeast culture in feed ration and studied its effect on digestion in sheep. Tegbe and Zimmerman (1977) tried the effect of same feed components in pigs. Water-washed neem seed cake as substitute for de-oiled rice bran in sheep and goat rations was reported by Ramu et al. (1994). Cotton seed hull was used as feed for poultry by Reddy and Reddy (1991).
c. Biochemistry of feed substitutes:

In livestock feeding exercises, it is now known that the fibrous feeds such as cereal straw and agricultural by-products are not fully utilized by animals due to complex nature of the substrate. Vast amount of potential energy is locked up in the form of lignocellulose molecules (Basham, 1975). About 3650 million metric ton per annum of cereal straw is available around the world (FAO, 1985).

During photosynthesis, about 95% of solar energy absorbed is fixed in the form of structural carbohydrate in plants. Of this, nearly 40% of energy is in the form of lignin (Kiran Singh, 1991) which forms a complex structure with cellulose and thereby protects the latter from enzymatic degradation by digestive juices of gastro-intestinal tract during herbivore feeding process. The enzymes required for breaking down of lignocellulose are known from a number of micro-organisms present in nature (Kalra and Singh, 1986).

Cellulose present in crystalline and amorphous form is the major nutrient component of fibrous feeds. Digestibility of this nutrient is affected because of its complex structural rearrangement with lignin. Thus, the primary requirement is to break the linkage between cellulose and lignin and thereby improve the digestibility of fibres.
d. Digestion of fibrous feeds:

Various physical, chemical and biological methods have been attempted to disrupt lignocelluloses and digest the fibrous feeds. Simple exercises such as soaking in water, cooking, crushing and microwave heat treatments have been tried.

Rangnekar et al. (1982) observed that the digestibility of roughages has increased when the feed source was subjected to high pressure steam treatment. Mahyuddin et al. (1994) reported the advantages of pelleting diets in the growth performance of sheep. Banerjee (1988) reported that irradiation of straw had improved its digestibility in sheep.

Chemicals such as sodium hydroxide (Garrett et al., 1979; Berger et al., 1980; Chesson, 1981; Patterson et al., 1983; Moss et al., 1990), calcium hydroxide (Sharma and Verma 1993), ammonium hydroxide (Sundstol et al., 1978) and urea (Agrawal et al., 1989; Prasad et al., 1993; Vinod kumar and Walli, 1994) have been successfully used in the treatment of straw and these resulted with digestibility improvement from 10 to 20%.
Although physical and chemical treatments can improve digestibility up to about 36%, biological treatments were shown to enhance the digestibility to a much greater extent (Kiran Singh, 1991). Several studies have been made on microbial degradation of fibrous feeds and agro by-products (Bisaria et al., 1987; Rajasekhara and Gulati, 1992; Neelakantan and Deodhar, 1993). Further, in view of nonavailability of desired chemicals and poor response of fibres to treatment, reluctance of farmers to adapt chemical treatment for straw digestion has been discussed by Mahendra Singh et al. (1993).

e. Role of microorganisms in the digestibility of fibres:

Nature has provided herbivores with a well-developed and microbially enriched digestive system with which the animals can efficiently degrade fibrous crop residues and other lignocellulosic waste and derive energy. Attempts have been made by several workers to take advantage of this biological phenomenon. Role of bacteria in the digestibility of fibrous feed in ruminant digestive system has been well recognized. Hungate (1966) estimated presence of a load of $10^7$ million bacteria per ml of rumen fluid.

Two well known species of anaerobic bacteria, viz. Rumenococcus albus and R. fluvofaciian, are said to play a major role in cellulose degradation and transformation into volatile fatty acids in the rumen (Barnett and Reid, 1961).
The role of anaerobic fungi in fibre digestion has also been studied extensively (Gulati, 1991). These organisms are generally active under anaerobic condition at a pH range of 6.4 to 7.0.

Teather (1985) made an attempt on genetic manipulation of rumen micro-organisms through gene cloning technique. The first attempt was to reduce the supply of outside protein to herbivores by increasing the level of production of amino acid by rumen bacteria. The second approach involved improving the rate of fibre degradation by bacteria. However, the work was difficult because several enzymes involved in lignocellulose degradation are produced by a number of organisms both within and outside the rumen. Through gene cloning technique, favourable genes were transferred from *Escherichia coli* to *Rumenococcus albus* in the rumen and the survival of the organism with synthetic gene under the rumen ecosystem was studied (Teather, 1985).

Several workers attempted to grow favourable microorganisms in artificial media and to use the microbial biomass as feed supplement (Moo Young et al., 1979). Some promising species of *Pseudomonas* were grown in methanol and conversion of hydrocarbons into bacterial protein was achieved (Zwatanov, 1988). Feeding trials conducted using single cell protein in young pigs and rats (Zimmerman and Tegbe, 1977) showed encouraging results. Kumar
et al. (1977) grew Bacillus in paddy husk and compared the structural carbohydrate changes occurred in the process with that of chemical treatment. Use of Lactobacilli as important organisms for enrichment of food has been reported by Rathna et al (1994). Schingoethe et al. (1984) fed dried cells of Lactobacillus acidophilus and L. bulgaricus to cattle and reported its effect on milk production. Maize meal fermented with L. plantarum when fed to broiler chicken showed no adverse effect on growth performance (Newman and Sands, 1984).

Conversion of carbohydrate into protein-enriched microbial biomass and further use as human food have been practiced for long. Consumption of fermented food product such as 'polu pedro' in south-east Asian countries was known since 18th century (Zadrazil, 1984).

The first attempt to incorporate yeast as food additive was made by Balling in 1865. Development of improved technology for production of food yeast as protein supplement for human consumption was described by Reed and Peppler (1973). Species of Saccharomyces and Candida were grown in alcohol for production of single cell protein from hydrocarbon. The harvested biomass was added to diet of poultry (Egorov et al., 1986; Bhatt et al., 1995), cattle
(Desai and Shukla, 1988; Kulkarni et al., 1994) and pig (Tegbe and Zimmerman, 1977) as substitute for protein in the ration.

The role of anaerobic fungi in fibre digestion has been extensively studied (Gulati, 1991). Since these organisms are active only under anaerobic condition at a pH range of 6.4 to 7.0, the scope of utilising them in field condition is limited. However, solid state fermentation by aerobic fungi for improving the digestibility has been attempted by several workers (Senez et al., 1980; 1979; Gupta, 1986; Valmaseda et al., 1991).

Brown rot, soft rot and white rot fungi were used in the degradation of lignocelluloses. Cellulose which is a polymer of glucose is degraded by hydrolytic enzymes whereas lignin, a phenolic compound, is degraded by oxidation processes (Kirk and Farrel, 1987). Gulati et al. (1986) used *Trichoderma reseii* for bioconversion of cellulose into soluble carbohydrate in sugarcane bagasses. Fifty percent increase in digestibility of bagasses was reported in cattle due to break down of the lignocelluloses during fermentation. Several workers have used species of *Agaricus*, *Phanerochaete* and *Pleurotus* as lignin degrading organisms (Zadrazil and Brunnert, 1982; Langar et al., 1982; Kakkar et al., 1990; Puniya et al., 1996).
f. Substrate enrichment through microbial fermentation:

Attempt was made by Han (1978) to enrich the wheat straw through microbial fermentation. Hatakka and Pirhonen (1995) cultivated wood-decaying fungi such as species of *Ganoderma* and *Phanerochaeta* on various agricultural wastes and concluded that the decomposed lignocellulosic material enriched with fungal protein may be a valuable feed.

Rai *et al.* (1993) studied effect of fungal growth on cotton straw under submerged culture condition. Santos and Gomez (1977) designed a starch fermentor for production of fungal mycelium in a liquid medium. Rodriguez and Enriquez (1985) used enriched liquid medium to grow appropriate fungi. In all these studies, the fungal mycelium was harvested and used for feeding the animals.

The process of bioconversion technology for agro-by-products are required to be simple so that it can be repeated and practiced at farmers' level. Wheat straw used for production of edible mushroom through solid state fermentation was tried as a possible feed (Langar *et al.*, 1982). The by-product, viz. the spent-straw, was evaluated for its nutritive value (Singh *et al.*, 1990). Gupta (1986) developed a novel method labelled 'Karnal Process' for enriching wheat straw using *Coprinus fimetarius*. Natarajan *et al.* (1992) reported
successful use of *Pleurotus citrinopileatus* in the biodegradation of paddy straw. Rajsekhara and Gulati (1992) recorded the effect of fungal biodegradation on chemical composition of cotton straw. Choudhary *et al.* (1994) fermented sugarcane bagasse using separately *Pleurotus florida* and *P. cornucopiae* and reported that lignin degradation was higher in *P. florida* inoculated sample. Arneja and Chahal (1992) used *Chetomium cellulolyticum* for fermentation of rice straw, with and without pretreatment, and indicated that pretreatment enhances the process without any adverse effect on chemical composition of the substrate. Considering these possible advantages, solid state fermentation was favoured for bioconversion of agro by-products using fungal principles.

In order to achieve enhanced rate of biodegradation, straw material was pretreated prior to inoculation by fungi by several workers. Kishan Singh *et al.* (1989) pretreated wheat straw with sodium hydroxide or ammonia and reported that 4% sodium hydroxide treatment gave maximum increase in crude protein content under submerged condition with *Aspergillus terreus*. Walli *et al.* (1991) studied the influence of urea on growth of *Coprinus filamentarius* and observed increased nutrient utilisation in calves. The digestibility of urea-treated straw was more in cattle than in untreated *Coprinus* fermented straw.

Choice of suitable fungi for fermentation of agro by-products is important in improving the process of solid state fermentation. In the selection of suitable candidate fungus, Sondhi et al. (1988) compared performance of 19 species of filamentous fungi in solid state fermentation of paddy straw. The biomass yield was higher in Pleurotus sojar-caju treated substrate than in other treatments. Kundu and Chawla (1986) inoculated different fungal species on wheat straw and reported that Alternaria tenuis and Chaetomium globosum caused maximum decrease in neutral detergent fibre content. Rai et al. (1986) attempted to improve the nutritive value of bagasse by fermentation with Trichoderma reesei and observed that both digestibility and crude protein content improved after 30 days of fermentation.
Although several attempts have been made to improve the nutritive value of straw through bioconversion processes, little effort was made on use of other agricultural wastes. Gulati (1991) used agricultural wastes as substrate for bioconversion. Leaves and tuber of tapioca were used as substrate for fungal growth by Alexander(1977). Cassava tubers enriched by nitrogen and inoculated with *Aspergillus niger* fermented into a protein-enriched feed called ‘cassapro’ (Kompiang, 1995). The feed could be prepared at village level and incorporated in poultry ration at 15% level.

Well over 20000 species of litter degrading fungi are known. A sizable number of these belong to Basidiomycotina (Kendrick, 1993). Among these, species such as *Phanerochaete chrysosporium* has been studied and is known to be highly lignolytic. Several species of edible mushroom fungi undertake lignin degradation. Rai *et al.* (1993) studied the lignolytic activity of 23 species of Basidiomycetous fungi and reported that *Pleurotus sajor-caju* colonised well on the substrate. Kishan Singh *et al.* (1989) reported that, when grown on paddy straw, *P. sajor-caju* and *P. florida* degraded lignin to same extent. Considering the capability of various enzyme production, safety and easiness to handle, *P. florida* has been selected for the present study.
Although several workers have used paddy straw and wheat straw as substrates for feed biodegradation, limited attempts have so far been made to use other agro waste material for conversion into animal feed. Evaluation of fermented banana waste as protein source in poultry development has been reported by Sethi (1983). Susan and Jeannett (1984) used citrus pulp as base for production of single cell protein with *Fusarium* sp. In view of its low investment cost and easy adaptability, these authors had followed solid state fermentation instead of submerged culture. Keeping these possible advantages in mind, degradation of substrate by fungi through solid state fermentation process was attempted in the present study.

**B. RABBIT PRODUCTION AND FEEDS:**

Rabbits are raised for a variety of reasons, and are found in virtually every country. Production of rabbits for meat has long been known in the European countries such as France, Italy and Spain (Cheeke, 1987).

Rabbit production in commercial livestock farming required only limited land and financial resources. With increased interest in ‘urban-farming’, rabbits were considered the better choice in the selection of suitable components (Cheeke, 1987). They can be raised in a small place and be fed with vegetable waste and by-products.
a. Advantages of rabbit as meat source:

Compared to other types of livestock animals, rabbits have a rapid growth rate and may reach market weight within 120 days from birth (Sundaram and Bhattacharyya, 1991). Rabbits can be successfully raised on feeds such as forages (e.g. leguminous tree leaves, grass forages, fruit-tree leaves, aquatic weeds, etc.) and grain-milling by-products (e.g. rice bran, corn bran and table scaps) which are noncompetitive with human foods. Being small in body size, rabbits require only small quantities of food. Rabbits have simple housing requirements; they make no noise and produce little odour (Cheeke, 1986). Vietmeyer (1985) termed the rabbits as ‘micro-livestock’, having great potential as a means of providing protein to the multitudes of low-income people in the developing countries.

However, a few factors currently limit the economic viability of rabbit for meat production. Rabbits are susceptible to many respiratory and enteric diseases due to malnutrition. Feed supply is the major limiting factor in rabbit production. World recognised rabbit expert Cheeke (1987) stated that improvement in feeding and better nutrition should make rabbit husbandry profitable.
b. Present status of rabbit-feeds:

Considering the existing market price of livestock feed commodities, the cost of balanced rabbit diet worked out to be approximately Rs.6.00 per Kg. Assuming that an animal consumes around 5-8% of its body weight feed per day, an adult animal requires about 100 gm of feed for a day (Cheeke, 1987; Sundaram, 1997). This would cost Rs 1.20 per day for feeding an animal.

c. Dietary requirements of rabbits:

Ruminant animals such as cattle and sheep have very simple nutritional requirements because the rumen micro-organisms produce the required amino acids, energy sources and most of the vitamins. Chickens require almost all known nutrients in their diet. Although rabbits are poor digesters of fibres, they are adapted to the utilization of fibrous feeds (Cheeke, 1983).

d. Fibrous feed for rabbits:

Observations on feeding behaviour of wild rabbits revealed that they require a diet of tender leaves and succulent plant parts (Van Soest, 1982). Rabbits are concentrate feeders, selecting high protein and high carbohydrate portions of plant material. However, rabbits are generally adapted to high-fibre
containing roughage feed, the digestive strategy being quick elimination of fibres from the gut and consumption of non-fibre constituents of the forage. Fibrous feeds such as alfalfa, clover, grass, etc. are typical rabbit diet. Alfalfa is 20-25% fibre and 75-80% non-fibre components. Separation of fibre from non-fibre in the feed takes place in the colon, with the fluids and small particles are utilized for fermentation in the cecum. The fibres are excreted as 'hard faeces' (De Blas et al., 1986).

Rabbits are hind-gut fermenters, the specific site of digestion being the cecum. All processes of digestion occurring in ruminants take place in the rabbit (Cheeke, 1987). Copropagy (eating of 'soft faeces'), consumption of cecal contents, a process comparable to remastication in cattle, takes place in rabbits and aids in the complete absorption and digestion of fibre containing herbaceous feeds (Robinson et al., 1985; Cheeke, 1987).

Various researches have shown that even though rabbits do not digest fibre very effectively they require a fairly high level of fibre in their diet (Cheeke, 1983). On studying the dietary effect on rabbits, De Blas et al. (1986) concluded that the growth rate was optimal with a low-energy and high-fibre (15-20%) diet. A high-fibre containing diet had less influence on reducing the protein availability to animals since cecotrophy is known to have increased the
nitrogen retaining capacity in rabbits (Hornicke and Bjornhag, 1982). High-fibre containing pelleted diet reduced enteritis and fur-chewing in rabbits (Harris et al., 1983; Cheeke, 1987).

It has become therefore necessary and important to identify alternate, nutritious, low-cost and balanced diet for rabbits using available fibrous agro-waste and other natural resources.